INTERIM REPORT ON

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Interim Report on the Development of the Rapid Selector

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I. The Problem of Data Handling for Analysis

A. The Major Requirements of Data Handling

For a large proportion of intelligence problems, the analyst must gather pieces of information from a great many sources and, by studying these pieces of information in relation to each other, piece together the more general picture that is required. The answer to any specific problem commonly does not lie in a few important documents, but rather results from collating all available data. Furthermore, this task cannot be accomplished by the use of indexes to the sources of information based on classification by a single variable, inasmuch as any single system of classification must either neglect important problems of cross classification and thus omit valuable material, or else make its categories so very broad that it cannot be a useful selective device.

Traditionally, the problem of complete indexing has been handled by the use of punchcards. It is customary to set up several decks of punchcards, ordered in different ways, so that the problem of machine processing can be somewhat simplified. For a number of problems, however, the punchcard indexing of material runs into serious difficulties. First, punchcards take up a large amount of space whenever the mass of material is large and a number of differently ordered decks are needed. Storage space is at a premium, especially for highly classified information, and both the containers and the space they take up are extremely costly. Second, the use of punchcards does not permit sufficiently rapid selection of information. If a conventional sorter is used, cards can be sorted on only one column at a time, and it may take a large number of sorts to obtain a desired selection. Even though the nominal rate of operation is six or eight hundred cards per minute, the necessity for sorting the cards a number of times reduces the actual speed of selection to a very much smaller figure. Third, once the desired punchcards are obtained, the original information is still not available. Customarily, the punchcard merely gives a number which must in turn be looked up in the file of original information. Fourth, both the withdrawal of punchcards for manipulation and the withdrawal of original information from the basic file for use by analysts destroy the integrity of the information. This difficulty is especially important where a great many analysts interested in different areas converge upon one topic which has aspects of interest to all of them. In such a case, the basic punchcard files will be continually disrupted in the exact area where the most requests are received. Similarly, the basic data from the file of original information will go to the analyst who asks for it first; unless some method of meeting requests with reproductions is instituted all the material will not be available to all users. Finally, although it may appear that a punchcard has considerable coding area, in practice it is often found necessary, in coding a single document, to employ a number of different punchcards containing additional information as trailers. The use of trailer cards slows the whole operation down, and introduces considerable complexity when any but the very simplest operations are attempted.

In view of these problems, it has been considered worth while to explore the possibility of developing some other mechanism of selecting desired pieces of information. One method which seems to overcome many of the difficulties listed above is that employed by Ralph Shaw in the Rapid Selector now at the Department of Agriculture. This machine uses coded 35 mm film containing, in addition to the code, a photograph of the original document. The code relating to one document can be interrogated in its entirety at one time. When material which answers the description of that desired is found, a copy of that material is made upon a separate roll of film which (after developing) can be given to the analyst to keep. The principal problem which arises with the Shaw machine in its present form is that its code area is somewhat restricted for the sorts of information searches that might normally be expected. If this difficulty could be overcome, however, a Rapid Selector based on the same general principles as the Shaw machine would for many purposes have a number of advantages over punchcard operations. First, the basic material would take up a minimum of space, since it would be recorded on microfilm rather than on punchcards and in file folders. Second, if the problem of interrogating larger code areas could be solved, the machine could be designed to have a larger coding capacity than is available with conventional punchcard machines. Third, the rapidity of selection would be much greater; the input into the machine would be in a continuous form, perhaps in reels of 1000 feet containing many thousands of cases, and each case could be examined on all columns simultaneously at a rate ranging from 1500 to 30,000 items per minute, depending upon the amount of code and the size of the abstract. Fourth, this system would maintain the integrity of the master file at all times, so that upon the completion of one search the basic material would remain available in its original form, completely accessible for any different search desired. Fifth, since a facsimile copy is provided for the analyst to keep, the original material is not tied up, and there is no necessity for a complex system of loaning, keeping track of, and re-collecting original material. Sixth, in situations where a casual inspection of the copy is all that is necessary, no further reproduction would be required, but when a document is found to be particularly useful the existence of a film copy would permit the use of automatic reproduction methods. Finally, in situations where continuous tone work is necessary (as distinguished from black and white line work), the use of photographic reproduction permits the continuous tonal gradations to be preserved.

It should be emphasized, however, that the Rapid Selector could take over only a part of the problem of data handling. For example, a device such as the Rapid Selector cannot efficiently arrange data in a perfect ordering, nor can it feed data into a tabulating machine to produce listings. For many purposes, these functions are very important. Punchcards would therefore continue to be the most efficient medium for certain phases of the data handling problem. The availability of a Rapid Selector using coded 35 mm film, however, in addition to enabling the performance of some operations more efficiently, would reduce the number of decks of punchcards needed, and would reduce the need for accessibility to the original information.

By developing the Rapid Selector to be complementary to punchcard machines, the advantages of both systems can be preserved. The initial coding of data could be accomplished by conventional punchcard methods utilizing existing machines and skills. By developing a machine to transform punchcards to dots on film and also copy abstracts, the problem of recoding would be avoided. This integration with conventional coding methods is especially important where punched cards are already in existence.

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B. Stages in the Process of Data Handling with the Rapid Selector

The development of a Rapid Selector involves more than merely refining the code interrogating portion of the Shaw machine, although this is the heart of the problem. It is important at this juncture to have a complete view of the process of data handling involved in the Rapid Selector and the various component elements that are necessary. The body of this report will be organized according to the various stages of the selection process which are deemed necessary for the successful operation of the system as a whole. Briefly, these stages are (1) the standardization of all abstract material with respect to physical size so that it can conveniently be put on 35 mm film by a fairly automatic process, and provision for the addition of intermediate information of various kinds before coding; (2) an automatic developing and reproducing process which can take unprocessed film and automatically produce both processed film and standard sized ordered prints; (3) preparation of the master 35 mm film, involving the transformation of the code symbols on punched IBM cards into black and white dots on the film, of an appropriate size and shape to be interrogated by the Rapid Selector, and the provision of a means by which these code segments can be related to the proper abstracts; (4) a method of discriminating among the various codes in such a way that any predesignated pattern can be selected; (5) a method of recopying that can, when triggered by the interrogator, make copies of the selected material on the master film while the film is being run through the selector at full speed; and (6) provision for enabling the analyst to view the recopy film in a clear enlarged image, and to obtain immediately whatever prints he may choose. These various stages in the process will be discussed in the following section in a more detailed manner.

II. Detailed Discussion of the Rapid Selector

A. Standardization of Abstract Material

Purpose

The abstract raw material which the Rapid Selector must deal with occurs, in its original form, in many different sizes and shapes. For purposes of machine handling, and to permit the development of standardized filing systems, this heterogeneous material must be converted to a uniform format. Initial preparation of the original material in a uniform size is not feasible, and facsimile reproduction is essential. Preliminary photographic recopying of the material in a standard size is therefore indicated.

Specific requirements

Since the flow of material that must be handled is very large, rapidity of operation is essential. To this end, as great a degree of automaticity as possible is desirable, including both automatic focusing and a non-manual method of altering the area to be photographed. The size in which the raw material occurs ranges from 2 inches by 3 inches to 10 inches by 15 inches; the camera must therefore be able to cover a range of from two times to ten times the negative size, if 35 mm film is used.

Solution

The solution adopted involved the modification of a Model D Recordak camera head by changing the lens, the focusing mechanism, and the lighting system, and adding a hydraulic drive mechanism. The Model D Recordak is designed to take photographs of varying sizes of material on 100 foot rolls of 35 mm film at a rapid rate, and incorporates a number of desirable elements of automaticity. However, it is designed to cover a size range of 10 to 20 diameters, as opposed to the 2 to 10 diameters required; it necessitates manual raising and lowering of the camera head on its supporting column as the area covered by the photograph is altered; and it uses a system of illumination (photoflood lamps) not well adapted to the material involved. It was decided, therefore, to use only the camera head of the Model D Recordak, with a substitute lens.

The lens adopted was a Kodak Ektar 101 mm f/4.5 projection lens. This lens makes possible the coverage of the 2 to 10 diameter range with a vertical movement of the camera head of 35 inches, which was judged to be the best combination obtainable without engendering complex lighting problems in the smaller magnifications when the camera head is in its lowest position.

Changing the lens, obviously, also required alteration of the automatic focusing mechanism. This mechanism keeps the camera in focus on the material being photographed at all times, regardless of the raising or lowering of the camera head to accomodate material of different sizes. Focusing, in the revised version, is accomplished by a cam on the vertical column.

In order to obviate the necessity for manual raising and lowering of the camera head, a hydraulic drive was added. This drive is of a fairly standard design. It is operated by means of foot pedals, which enable the operator to use his hands solely for the arrangement of the material being photographed.

The lighting system, for reasons of both operator comfort and Agency convenience, is being changed from photoflood lamps to electronic flash lamps. However, with a new calibration scale the same mechanism for determining light intensity and exposure can be used.

B. Automatic Developing and Printing

Although the development of an automatic developer and printer is
25X1A5a1 being carried on separately [redacted] it is a necessary part of the complex of equipment required to meet the objectives of the project, and will therefore be described briefly here. At the present time this equipment is in the process of development (primarily for another purpose) and should be available shortly.

Purpose

The Automatic Recordak delivers undeveloped 100 foot rolls of 35 mm film. From these must be obtained paper positive prints of uniform size, mounted on filing cards containing also a printed form for entering additional information. These filing cards, with the photographs mounted on them and any additional information entered in the appropriate places, constitute the abstracts that are the units with which the remaining components of the Rapid Selector will deal. It is these abstracts which the machine is required to recall, select, and deliver. Because of the quantities of material involved in the daily flow, an automatic method of developing the negatives, printing them, mounting the prints, and arranging the prints in the order of the negatives is desirable.

Specific requirements

The pictures are to be printed in a uniform 4 inch by 5 inch size, and mounted on cards of 5 inch by 8 inch size containing also a specific blank form to be filled out at a later stage. The abstract cards are to be delivered in the order in which they occur in the negative rolls.

Solution

It is not at present considered feasible to combine negative development with the making of paper prints, and a separate process of automatic negative development will therefore be used. For the rest of the process, the Eastman Kodak Company is developing an automatic printer which will utilize rolls of 5 inch double-weight paper, on which both the individual photographs (in the required 4 inch by 5 inch size) and the standard blank forms will be printed, thus avoiding the necessity for a separate mounting process. The printer will embody a mechanism for determining electronically (by a scanning device and a phototube) the appropriate exposure for each negative. The prints will be retained in roll form until the processing is completed, thus retaining the negative order. At the end of the process, the rolls will be run through an automatic cutter, so that they are finally delivered as individual cards.

C. Preparation of the Master Film

Purpose

The purpose of this phase of the process is to prepare from the abstract cards the master film from which selection is made. The master film (positive or negative as desired) embodies sequentially an abstract, in a standard 24 by 35 mm frame, and a section of black and white dot code area of varying length, as described below. The output of this component, which may be termed the encoder, is undeveloped 35 mm film in 100 foot reels, which are then developed (and copied, if desired) by conventional means.

Specific requirements

The rephotographing of the abstract cards themselves presents few problems. The following discussion will therefore be confined largely to the preparation of the code segment.

For reasons of integration with existing equipment, as well as simplicity, it is required that the coding system be a simple transformation of IBM punchcard coding, and that the transformation be accomplished automatically from punchcards. The amount of code information for each abstract will vary from one to five punchcards in the usual case; however, provision is also required for a special short frame having a half-sized abstract, with coded information beside it equivalent to half a punchcard.

Initial preparation of the punchcards will be by conventional means, involving the preparation of the code information by analysts and punching of cards on a standard key punch. Where abstracts and code are used sequentially, manual feeding of the encoder will be accepted, but provision is also required for automatic feeding of punchcards alone in special cases when no abstracts are used.

Solution

The preparation of the punchcards embodying the coded information will be done in the conventional manner. The input to the encoder proper, therefore, will consist of a pile of alternating punchcards and abstract cards. The process involved in the encoder may, for convenience in exposition, be divided into two parts: the transformation of the code to a form suitable for photography, and the actual photographing of the code and the abstract.

Direct photography of punchcards was considered and abandoned, on the grounds of extreme inefficiency in the utilization of the available film area and the excessively close tolerances which would be entailed. The holes in an IBM punchcard (if all punched) occupy only about 27 per cent of the available area. The punch hole is a rectangle, approximately .008 inch by .017 inch, with the long dimension along a column. However, for reasons which can best be pointed out below in the discussion of the interrogator, the critical dimension in terms of tolerance in the Rapid Selector is lateral rather than longitudinal.

To avoid these dimensional problems, the punchcards, instead of being photographed directly, will be used to light selected lamps in a bank of lights having the same number of bulbs as there are possible punch positions on a punchcard--i.e., 960. These lights will be separated from one another by barriers, and will emit their light through ground glass screens. It is apparent that these light spots can be made of any desired shape, and that the arrangement of the raster is not restricted to the 80 x 12 form used in the punchcard. Discussion of the pattern and dimensions adopted will be deferred to the section on the interrogator, where the reasons for the arrangements adopted can be made clear.

The transformation from punched cards to lighted lights will be made by means of a modified Remington Rand Sorting Machine. The present sensing head on this sorter will be replaced by an electrical sensing head, which will be designed to accomodate IBM rather than Remington Rand cards, and which will read all columns of a card simultaneously.[1] Whatever the number of code cards used with any given abstract (one to five), each will be fed into the sensing head individually, and each will light the bank of lights separately.

The camera to be used in the encoder will be another modified Model D Recordak. It will be adapted to take two specific picture areas: the 5 inch by 8 inch abstract card (equivalent to a film area of 24 x 32 mm), and the area of the light raster. The Model D Recordak incorporates a variable frame size as one of its standard features, so that the shape of the light raster will raise no problems. The light raster will be imbedded in the operating table of the Recordak. Part way up the support column, a swinging table will be installed, upon which the abstract cards will be placed. By means of a cam driven by this swinging table, the camera lens will be moved (or an auxiliary lens inserted) so as to focus on the light

1. It is of interest to note that a somewhat similar system, which uses the electrical sensing head in conjunction with the sorting machine to flash lamps, but for a different purpose, is now in successful operation in the research laboratory of the Remington Rand Co., at Norwalk, Conn.

raster when the table is swung out of position and on the swinging table itself when it is in position. Figure 1 shows the proposed arrangement of the elements of the encoder. In normal operation, the one to five punchcards associated with a given abstract would be inserted in the sensing head first, individually and in the proper order, and the light raster associated with each photographed successively, with the swing table out of the way. Then the table would be placed in position, with the abstract card on it, and the abstract photographed. To handle the special short frame, use could be made of the variable frame size of the Recordak.

D. Interrogation

Purpose

This is the point in the process at which the actual selection is done. The purpose of this specific component is to select from the master film (or a copy thereof) specific units of information--one abstract or one abstract plus its code, as desired--for which the code matches the desired pattern, and to produce an output signal indicating which information units are hits, i.e., agree, and which are misses. The output signal indicating hits and misses must of course be timed according to the rate of movement of the film, in order to arrive at the next stage, the recopy camera, at the proper time.

Specific requirements

The primary specific requirements for the interrogator, apart from the general considerations already covered, relate to flexibility of operation. The amount of code area should be variable by discrete intervals--i.e., by intervals of one punchcard--so that it can include from one to five

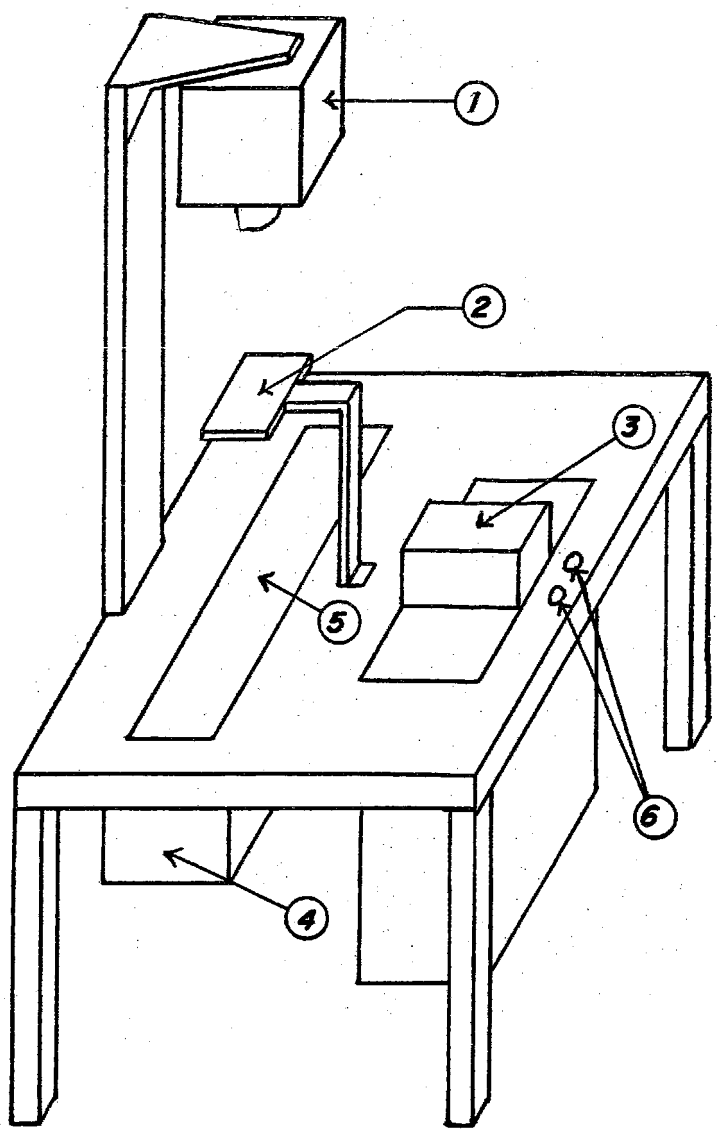


Figure 1
Encoding Machine

(1) CAMERA

(2) MOUNT FOR 5"x 7" ABSTRACTS. When mount is in position shown, camera is focused for photographing abstracts. Mount swings toward front of machine when the light raster (5) is photographed.

(3) SENSING HEAD. This unit "reads" all columns of an IBM card at the same time and sends this information to the translator (4).

(4) TRANSLATOR. This unit energizes the proper lights in the light raster.

(5) LIGHT RASTER. These lights convey the code of the IBM card.

(6) CONTROLS: Operation of the machine is as follows:

(a) Operator lays the IBM cards (up to five) in the sensing head and presses the "Submatrices" button, whereupon the mount moves out from under the camera and the light raster is photographed.

(b) Operator lays the abstract on the mount and presses the "Abstract" button, whereupon the mount moves under the camera and the abstract is photographed.

punchcards. The portion of the code area examined should be variable. The order in which examination of the various code areas takes place should be variable. If a code area of less than five punchcards is examined, opportunity should be provided to examine some portions more than once. For example, if a code area of only one punchcard is examined, it should be possible to examine it five times, either with the same question repeated or with different questions. In general, the requirement of flexibility is a requirement that the specific method of searching be fixed as little as possible in advance; instead it should be made to depend upon either the composition of a specific master film or upon the characteristics of a specific search.

Possible solutions

As indicated above, the design of the interrogator is the heart of the problem of developing the Rapid Selector. In terms of manhours spent by the professional staff, almost all of the effort expended to date has gone into this particular aspect of the work. A great many different possible solutions have been investigated, and it would be too space-consuming to attempt to record the details of all of these investigations. However, it will be useful here to go into some detail about a number of major variants that may offer possibilities should the lines along which the project is now proceding meet with serious obstacles. These major variants may for convenience be classified in four broad groups: (1) systems using flying-spot scanners; (2) systems using the iconoscope or a related device; (3) the sequential-blackout system; and (4) the multiple-phototube-blackout system. The first two groups of systems listed above have been explored mainly in terms of conferences, consultations, and discussions with other people in the field and among the consultants working on the project. These systems have not been rejected, but are rather being held in reserve for the time being until the more promising lines of investigation can be followed up. The third system, the sequential-blackout system, has been explored in the greatest detail, and a number of different experimental models set up to test the characteristics of various components used in this system. From such experiments, rather detailed design has been possible, including specific dimensions of the code dots and areas required. The fourth system listed, the multiple-phototube-blackout system, is an outgrowth of certain aspects of the sequential-blackout system. In fact, it was developed to avoid some of the difficulties encountered in the channeling of light in the sequential-blackout system. It is as yet too early to tell which of the last two systems will be simpler from a fabricational and operational point of view, but both systems seem to hold a great deal of promise.

Before undertaking a discussion of these various systems of interrogating 35 mm coded film, a preliminary discussion of the original Shaw Rapid Selector and the general principles which apply to all systems of interrogating coded film will greatly simplify the subsequent discussion of the specific systems.

The machine developed by Ralph Shaw of the Department of Agriculture and built by Engineering Research Associates, Inc., is the prototype for the Rapid Selector now being developed. In this machine, the code on the 35 mm film is a modified binary system involving two punches out of five possible positions. The amount of code that can be accomodated in the code area is very limited. The manner in which the code is interrogated is as follows. A beam of light is projected through the film and an enlarging lens onto a set of phototubes. By interposing a mask between the phototubes and the projected image, it is possible to test any designated portion of the projected area electronically for the presence or absence of light. In the Shaw machine, the mask is made the complement of the desired code, so that whenever the desired code pattern appears only black spots from the film will be projected onto the exposed phototubes, and there will in effect be a blackout over the phototubes. In other words, the cardboard mask is the complement of the code desired, so that only those film codes having the black spots in specific areas will be recorded as hits. This is the essence of the blackout method of interrogation.

Any system of interrogation of coded 35 mm film, blackout or other, must involve the checking of the code on the film against some other code which embodies the interrogation. The interrogating code may of course be recorded in any form that would lend itself to simple electrical translation. It could be a cardboard mask, a pattern of phototubes, an interrogator film, an iconoscope camera tube on which the code is recorded by stored electrical charges, or a magnetic tape or drum on which the code is recorded by stored magnetic charges. The actual interrogation of the code on 35 mm film must always be accomplished in some sort of optical manner, by projecting light through the film; but since there is no simple way of making an optical comparison itself actuate mechanisms, an electrical circuit is required somewhere in the system. In the Shaw machine, for example, the optical result of the interrogation was converted to electrical form by phototubes.

The comparison between the two codes may be made by examining them sequentially point-by-point or by matching or testing entire dot patterns simultaneously. In a point-by-point sequential comparison, for example, one interrogator head might survey the code being interrogated while a second head surveyed the question code, the two outputs being compared electrically. In matching dot patterns simultaneously, on the other hand, the complete image of the code on the film might be projected optically against a question mask, or tested by phototubes for light and black in specific areas.

In those cases where comparisons of codes are made sequentially point-by-point, the outputs of the two optical-to-electrical converters involved must be identical at each instant of time in order to record a hit. Where a large area is examined at one time, however, a hit is recorded if a given pattern of dots is found at any single instant, rather than at every instant. It is evident that the simultaneous examination systems, of which blackout systems are a principal class, offer much wider tolerances, both in mechanical alignment and in synchronization, than do the sequential systems.

<u>The flying-spot-scanner systems</u>. The first modification of the Shaw interrogator that was considered involved the use of a flying-spot scanner. A flying-spot scanner is a means of generating a movable spot of intense light by the impact of electrons on the face of a cathode ray tube. By electrical means this spot may be made to traverse a series of equally spaced paths across the face of the tube. A beam-splitter--a half-silvered mirror that has the property of breaking up an incident beam of light into two component beams--would be used in conjunction with the flying-spot

scanner. The two resulting components of the beam generated by the flying-spot scanner would simultaneously scan the interrogating code and the code being interrogated. Two phototubes, one behind each code, would convert the light signals produced into electrical signals, which would then be sent to a comparison circuit.

In a variation of this system, the two codes might be aligned between the light source (flying-spot scanner) and the phototube, thus eliminating the need for the beam splitter.

This flying-spot-scanner system (or some variant of it) appears to hold considerable promise. Since it is a point-by-point sequential comparison system, however, the problems of mechanical alignment and of maintenance of exact synchronization between the light beam and the film advance are quite severe. In addition, the electrical pulses occur at the dot-repetition frequency, which will be quite high, so that difficult electrical problems will be involved in maintaining the time coincidence of the two pulses in the comparison circuit. For these reasons, and since the time alloted for the development of a machine was limited, further consideration of this method was deferred for possible later study.

<u>Iconoscope-scanner systems</u>. The second group of interrogating systems considered involve the use of a camera tube such as an iconoscope. An iconoscope is a tube in which an optical image of the scene under survey is converted into a corresponding array of electrical charges on a photoelectric mosaic located on the inside face of the vacuum bulb. "hen this charged mosaic is scanned by an electron beam, electrical pulses corresponding to the electrical charges on the elements of the mosaic are transmitted to an external circuit.

The first version of the iconoscope-scanner system considered would use two iconoscopes, one in conjunction with the interrogating code and one in conjunction with the code being interrogated. Flash lamps triggered when the code to be interrogated is aligned with its iconoscope would convert the optical images of the two codes to electrical charge images on the mosaics of the two iconoscopes. The two tubes could then be scanned simultaneously by their own electron beams, and the two outputs sent to an electrical comparison circuit.

One of the outstanding advantages of this system is that the electrical charge produced on the mosaic of the iconoscope is relatively long-lived, so that the entire time during which the film advances from one code frame position to the next could be used for the scanning process. By the use of identical flash tubes, identical iconoscope tubes, identical scanning mechanisms, and identical film material for the interrogating and interrogated optical images, the electrical comparison problem is much simplified. The mechancial alignment problem between question code and the code to be questioned is similar to that arising in the flying-spot-scanner systems.

Several variants of this system using different camera tubes were considered. The image orthicon tube used in place of the iconoscope would give an increase in electrical output for a given light signal. Alternatively, a vidicon tube would give an increase in compactness and ruggedness.

A critical problem which arises with the use of any of these camera tubes is the necessity for complete scanning of the face of each tube by its electron beam after an image is placed on it in order to remove all electrical charges completely, so that the next electrical image is placed on a neutral mosaic. This problem is particularly acute when the vidicon tube is used.

Another group of varients of this system involve the use of a magnetic storage device such as a tape, disc, or drum. In these variants, the question code would appear as an array of magnetic charges on the magnetic storage device. A camera tube would still be used to obtain an electrical image of the code being interrogated. These two sets of stored images would then be read out together into an electrical comparison circuit. Various magnetic storage devices of this nature have been developed for use in electrical computing machines. Dr. Jacob Rabinow, of the U. S. Bureau of Standards, who worked with Dr. Shaw on the initial Rapid Selector, has developed a magnetic disc which has very interesting possibilities. Engineering Research Associates, Inc., has a line of magnetic drums that are now in commercial production.

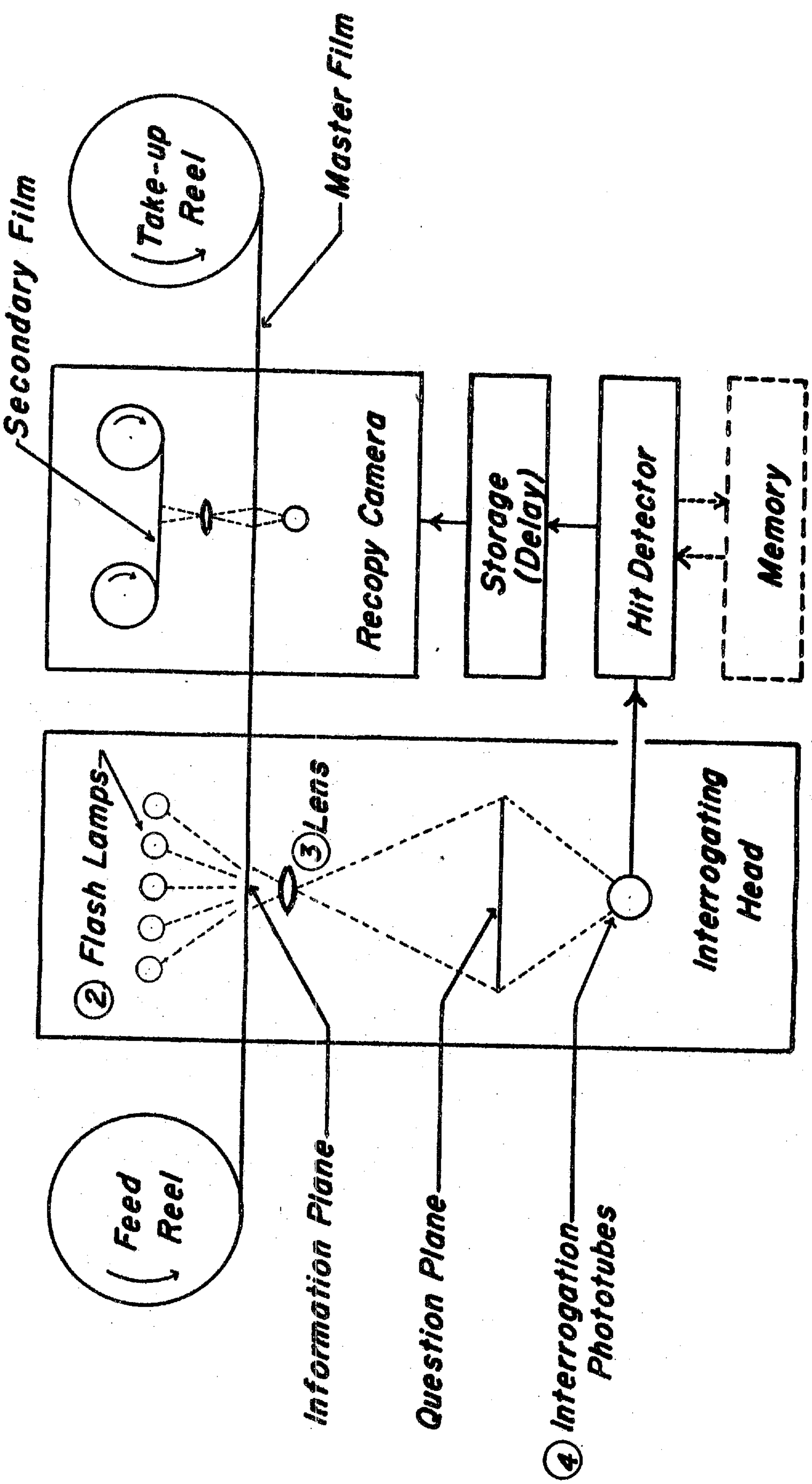
The final, and major, variation of the iconoscope-scanner system that was considered would use what is essentially a blackout or simultaneous system of interrogation, as opposed to the point-by-point sequential interrogation used in the other variants of this system. In this variant, the interrogating mask and the interrogated code would be aligned together between the flash lamp and the iconoscope tube. The iconoscope image would then consist only of those areas not blacked out. The existence of a single spot anywhere on the iconoscope would indicate a miss. Since comparison of two tubes would not be necessary, most of the synchronization problem is avoided. The mechanical alignment problem would remain, however.

Again, further study of the various iconoscope-scanner systems was deferred for possible later consideration.

<u>The sequential-blackout system</u>. The third system of interrogation considered involved the use of a sequential series of blackouts. As indicated above, the sequential-blackout system has been considered in greater detail than any of the other systems. Tests have been conducted on both a static and a dynamic basis. These tests have given a considerable amount of design information and have delineated the major problem areas. For this reason, the following discussion will be considerably more extensive and detailed than the discussion of the previous systems.

A block diagram of the overall scheme of the sequential-blackout interrogator and the recopy camera is given in Figure 2. In this system, the light is passed through the coded area of the film and then through an interrogating mask punched with appropriate holes; a phototube then tests whether the amount of light transmitted is greater or less than some suitable reference level. Failure to transmit light equal to or greater than the reference amount indicates success in matching the two codes, and is known as a hit. Although this process is conceptually quite simple, the apparatus required to accomplish this interrogation and transmit the results to the next stage is sufficiently complex so that a further breakdown of the process will facilitate the discussion.

As Figure 2 indicates, the components of the interrogator are the interrogating head, a hit detector, a memory, and a storage element.



LAYOUT OF RAPID SELECTOR

FIGURE 2

(In the present model the memory element will be omitted in order to expedite the construction.) The mechanics of operation of the system are as follows. Question masks are inserted into the interrogating head. Film is then transported through the interrogating head, to the recopy camera, and to the takeup reel. As the matrices pass through the interrogating head, they are questioned. When a positive answer is obtained from the interrogating head, the hit detector directs a pulse into the storage element. This pulse remains in the storage element for a time corresponding to the time of transit of the interrogated matrix from the interrogating head to the recopy camera. When this matrix arrives at the recopy camera, the storage element directs a pulse into the recopy camera, thus priming the film mechanism in the recopy camera and motivating the actual recopying of the matrix and its abstract onto the copy film. This section will consider in turn the following aspects of the problem: (1) the composition of the master film; (2) a detailed discussion of the interrogating head proper; and (3) the control mechanism.

The master film, as indicated in the section on the encoder, consists of a section of black-and-white dot code followed by an abstract. In the section on the encoder, considerations of the arrangement of the code and the dimensional characteristics of the film were deferred. They can now conveniently be discussed. The 35 mm film has a usable width of 1.470 inches. Of this, a certain portion must be reserved for margins, and another portion for control columns (the use of which will be discussed below). The portion of the film available for code is 0.945 inches. The possibility of dividing this width into the 80 columns required for the punchcard coding system was considered, but rejected on the ground that the lateral tolerances involved--in film movement, shrinkage, placement of the code on the film, etc.--were sufficiently close to require the use of some sort of servomechanism, thus introducing an element of complexity that might be avoided by the choice of a different code arangement. It was decided, therefore to use instead two successive groups of 40 columns. This procedure would permit each dot to be 0.022 inch wide, an amount which was judged to provide adequate tolerance. The information from one punchcard, thus, would be arranged in two bands across the width of the film, each of 40 columns of 12 dots. This arrangement of 40 x 24 dots is called a <u>submatrix</u>. The information from succeeding punchcards, up to five, would be arranged in a similar manner following the first; thus there might be up to five submatrices. The entire code area is termed the <u>matrix</u>. The longitudinal dimension of the dot was determined on the basis of timing considerations: the speed of the film in relation to the duration of the interrogating light. These considerations indicated that a length of 0.010 inch would be generous. One submatrix would thus occupy a length along the film of 0.24 inch, and five submatrices, 1.2 inches. Figure 3 shows the arrangement of the master film in some detail. (This figure introduces certain elements of nomenclature which have not yet been defined; they will be introduced below as the need for them arises.)

Figure 4 shows the interrogating head in perspective. The elements of the interrogating head are as follows: (1) five flash lamps, which produce collimated light beams to illuminate respectively areas 1, 2, 3, 4, and 5; (2) a constant light source that illuminates the area under which

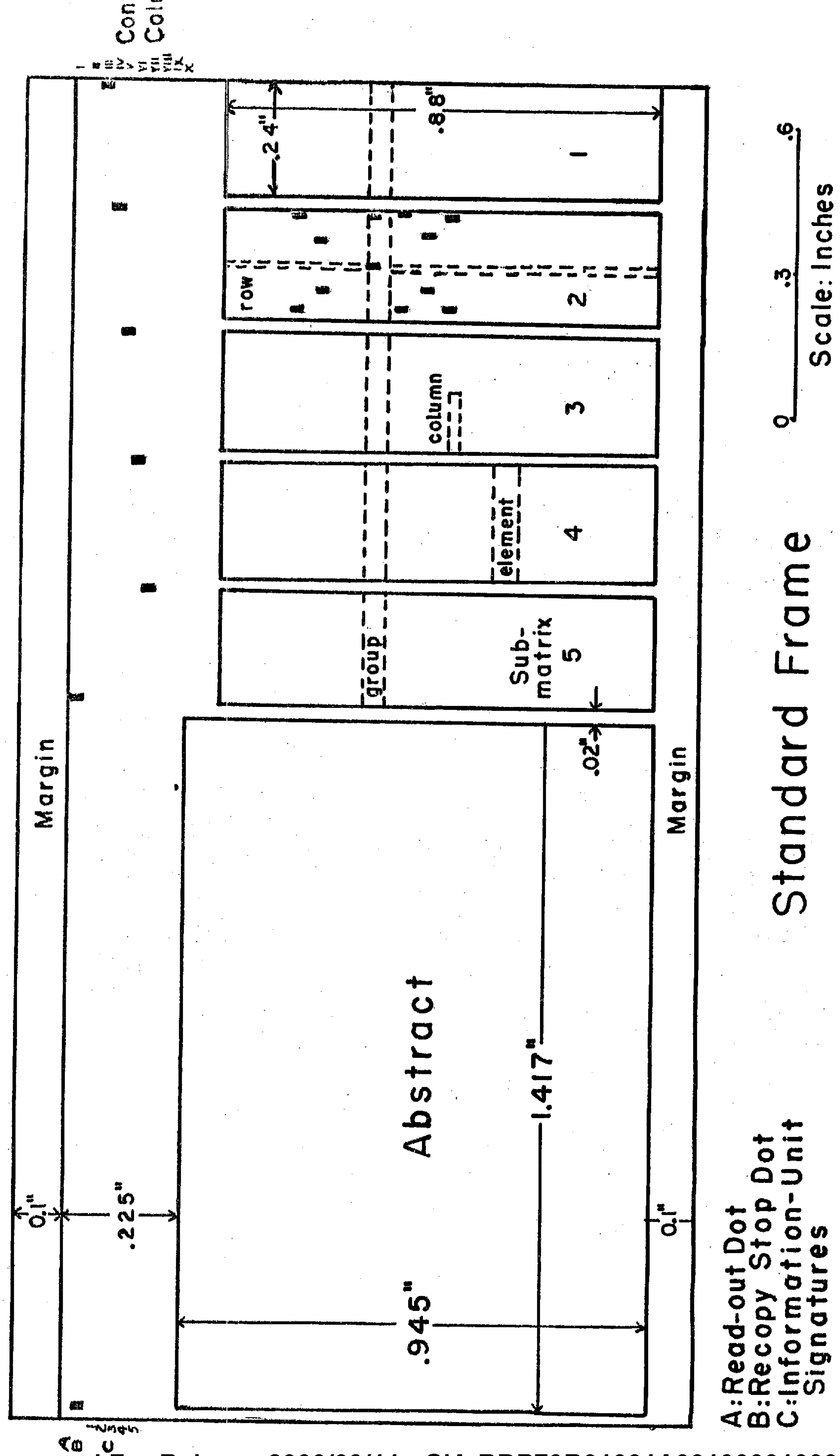

Control Columns
I II III IV V VI VII VIII IX X
Margin
Abstract
.945"
1.417"
.225"
0.1"
.02"
.24"
.88"
row
column
element
group
Sub-matrix
1
2
3
4
5
Margin
Standard Frame
0 .3 .6
Scale: Inches
A:Read-out Dot
B:Recopy Stop Dot
C:Information-Unit Signatures

Figure 3

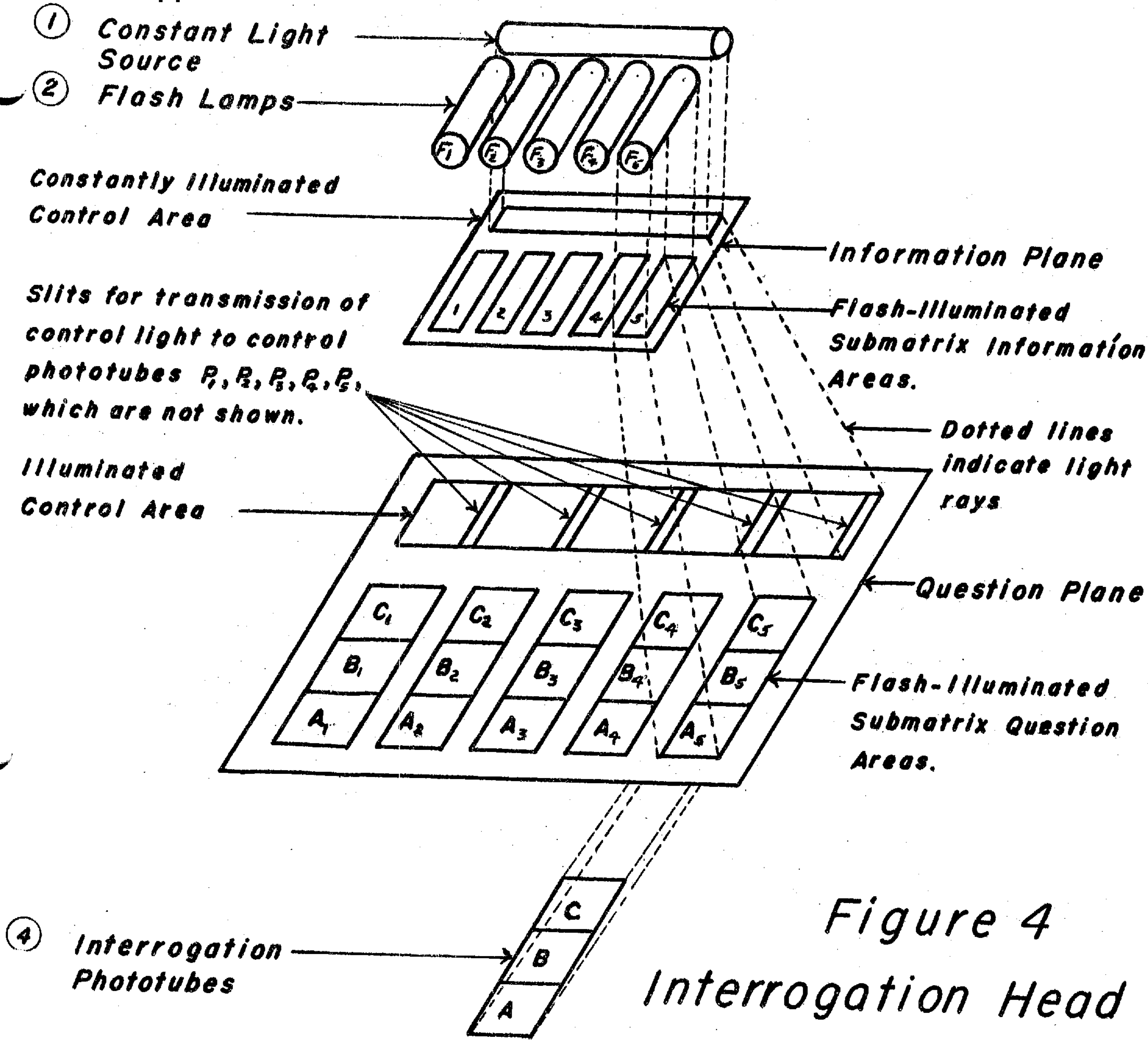


Figure 4

Interrogation Head

The information plane is projected onto the question plane by means of a lens (not shown).

Light through regions marked A, B, C, etc. is collected by interrogation phototubes A, B, C, etc., respectively.

the control columns of the film pass; (3) a lens that focuses the illumination that has passed through the master film onto the question plane, i.e., the mask (enlarging the image in the process), as shown in Figure 4; (4) interrogation phototubes A, B, C, etc., for receiving the light that passes through the question areas of the mask; and (5) control phototubes that receive the light that passes through the control area of the mask (these latter phototubes are not shown in the figure). The collection of light from the illuminated question areas in the mask is accomplished in such a way that any light falling on the subregion marked A is directed to interrogating phototube A, that from subregion B to interrogating phototube B, etc. In operation only one flash lamp will be illuminated at a time. Consequently light will be directed to the interrogating phototubes A, B, C, etc., from only one illuminated question region at a time. The subregion of one submatrix on the master film from which the light is directed to an individual phototube is termed an <u>element</u>, and the corresponding elements from all submatrices, from which the light is directed to the same phototube at successive points in time, is called a <u>group</u>. These concepts are illustrated in the diagram showing the arrangement of the master film, Figure 3.

The permissible size of an element, i.e., the area that can be examined at one time by a single phototube, can be determined experimentally. Developed photographic film is never completely opaque, so that some light will be transmitted through the black code dots on the film. It has generally been found that the light transmitted by between 10 and 15 black dots will equal that from one white dot. There is therefore a definite limit to the number of black dots a single phototube can examine, without reporting hits as misses. Pending further experimentation, it has tentatively been decided to restrict the area examined by one phototube to four to eight black dots, which is equivalent, with standard IBM coding, to four columns. These columns are chosen so that they include two columns from the first band of a submatrix, and the corresponding two columns from the second band of that submatrix. An element is thus tentatively set at an area two columns long and two columns wide.

A submatrix is interrogated when it is illuminated by a flash lamp. A hit is obtained when no light is transmitted through the submatrix on the film and through the mask to the phototube. A miss is obtained when light does reach the phototube. Consequently, when a miss occurs, there will be a pulse output from the phototube. This pulse is stored in the hit detector. At the completion of the interrogation of the entire matrix (up to five submatrices), the hit detector is itself examined to see whether it contains any stored pulses. If it has any stored pulse, the matrix did not satisfactorily answer the question. If there is no stored pulse, the matrix did satisfactorily answer the question, and the frame is to be copied in the recopy camera.

It would not be satisfactory if the recopy camera were immediately actuated upon detection of a hit, since it would then start copying at a time considerably before the designated abstract reached it. Since the recopy camera must be located at some distance beyond the point of actual interrogation, some method of delaying its operation must be employed. At the present time, it is proposed that a magnetic tape or disc, synchronized with the average speed of the film, be used as a storage delay so that the recopy camera will perform at the correct time. The control mechanisms by which the flash tubes are flashed, the hit detector is examined, and the recopy camera is triggered will be discussed below.

There are three light-transmission paths in this interrogation process: (a) from the flash lamps to the film, (b) from the film to the interrogator mask, and (c) from the mask to the phototubes. The second of these, because it involves the enlargement of the image, requires a lens system. The other two light transmission paths could utilize lenses, prisms, or mirrors, or a combination of these. At the present time, however, experiments are being conducted with methyl-methacrylate, which is sold under the trade names of Lucite and Plexiglas. This is a transparent plastic with a light-transmission efficiency of 92 per cent. The major problem in light piping will occur in the path between the interrogator mask and the phototubes. The input window, or cathode area, of the phototubes which seem best adapted for this use is 0.94 inch by 0.32 inch. One tube will examine the group of corresponding elements from as many as five submatrices, or a total length on the film of 1.28 inches. An eightfold enlargement of the image as it is focused upon the mask is presently contemplated, yielding a length of 10.24 inches at the interrogator mask. The width of an element, on the present assumption of two columns, would be 0.04 inch on the film, or 0.32 inch enlarged at the mask. The problem thus becomes one of transmitting light equally well from each of the five submatrices, in a total area of 10.24 inches by 0.32 inches, to a cathode area measuring 0.94 inch by 0.32 inch, without serious loss. At the present time, insufficient information is available to determine definitively whether such light piping will work satisfactorily. If not, a system of mirrors or lenses might be employed. In any case, this particular problem seems to be one of the more difficult ones encountered to date. Preliminary tests indicate that there will be no serious difficulty in using Lucite or Plexiglas to pipe the light over the remaining transmission path, from the flash lamps to the film. It may be desirable, however, to use a parabolic reflector behind the lamp to produce a parallel beam of light, with opaque separators between the five beams.

Up to this point, the mechanism for synchronizing the operation of the various components of the interrogator has not been discussed. Nothing has been said about triggering the flash tubes, determining their order of firing, operating the hit detector, etc. Previous sections have discussed the operation of various components of the interrogator under the assumption that the flash tubes would flash at the proper time, and that the hit detector would be examined for stored pulses at the proper time. This section will discuss the method of control by which the proper timing is obtained.

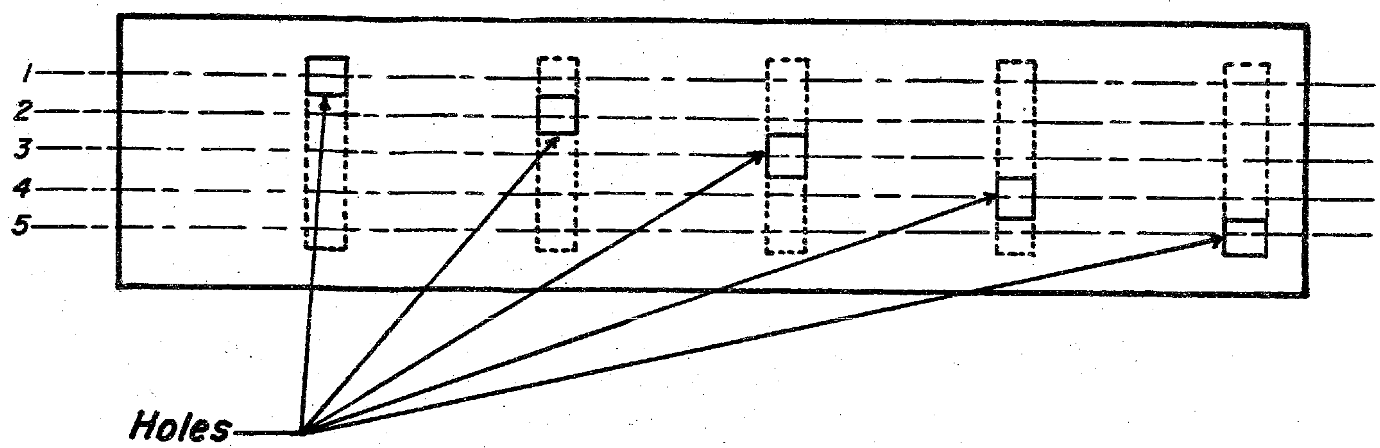
The principle has been adopted that all control of timing should be accomplished by marks on the film passing fixed points in the mechanism. Any attempt to employ a fixed time interval for achieving synchronization between the movement of the film and the operation of the various components was rejected on the grounds both that it would be too difficult to synchronize the rate of passage of the film with fixed time intervals and that fixed time intervals would not permit the required flexibility in operation.

In the arrangement of the code and the abstract on the film provision has been made for 10 columns in which control dots may be placed, at one edge of the film. These control columns are illustrated in Figure 3 above, marked I through X. (In the present conception of the operation of the sequential-blackout interrogator, only seven of these columns are needed; the other three are included for possible uses to be determined as the development of the machine progresses.)

As noted above, there are five flash lamps, one for each of the five different question masks. In interrogating a particular submatrix, the proper flash tube must fire when the film code is directly superimposed over its question mask. This synchronization can be accomplished by having a submatrix signature control dot in one of the control columns black out a phototube that activates the appropriate flash tube. For example, if the first question mask contains a hole in control column one, this hole will only be covered by those film submatrices which have a black signature control dot in this particular control column, and only when the black dot on the film is aligned with the corresponding hole in the question mask. If it were desired that the first question mask should interrogate submatrix two rather than submatrix one, it would merely be necessary to place the hole in the mask in a position corresponding to that of contol column two. In other words, by identifying the various submatrices on the film by signature dots in five different control columns, the five different submatrices of any given matrix can be distinguished. The order of firing the flash tubes will be determined by the manner in which the question masks are punched, and alignment between the film and the mask at the point of when the flash tube fires will be assured, when the control phototube is blacked out.

The control mask shown in Figure 5 illustrates one possible order of firing the flash tubes. It is readily apparent, however, that this technique admits of great flexibility. The flash tubes may be fired in a number of different orders, making possible a great many different types of interrogation. For example, if the information coded in one or more of the submatrices is missing for a particular abstract--say, for example, submatrices 2 and 4--these two submatrices can simply be omitted from the film, without leaving blank spaces for them. The signature dots in the control columns for the submatrices that are present will still insure that the proper flash tubes are fired at the proper times, so that submatrices 1, 3, and 5 are interrogated by the proper masks. Or, alternatively, in a particular interrogation it may be desired to ask more than one question of submatrix 1, without asking any questions of the remaining submatrices. The proper arrangement of the signature dots could cause each flash tube to fire as submatrix 1 passed under it, so that, with the insertion of a different question mask corresponding to each flash tube, five different questions could be asked of submatrix 1. To make the greatest possible use of the flexibility offered by the machine, a memory element must be incorporated in the system; otherwise certain orders of firing and certain arrangements of code on the film will be found to be incompatible. For the sake of simplicity, however, such a memory element would probably be omitted from an initial model, in spite of the loss of flexibility.

Of the remaining control columns, one is used to control the hit detector. When one of the interrogating phototubes scores a miss, there



CONTROL MASK - FIGURE 5

Mask is placed on the question plane with the dotted area lined up with the slits (See Figure 3).

Lines marked 1, 2, 3, 4, 5 identify paths taken by the information-unit signatures (black dots found in the signature control columns that identify the submatrices).

Within a particular dotted area, the holes may be centered on any one of these five lines depending upon the type of interrogation.

Control phototubes are placed so that each of the phototubes "looks" for blackout anywhere along its slit.

will be a pulse output from that phototube. This pulse output is in turn stored in the hit detector. At the end of the interrogation of a particular matrix, the hit detector is itself examined to see whether or not it contains a stored pulse. If there is no stored pulse, this matrix agrees with the question mask and so constitutes a hit, and should be recopied by the recopy camera. The examination of the hit detector to see whether or not a hit has been obtained is controlled by a read-out dot in the read-out pulse column of the control area. This read-out dot is shown in Figure 3. The read-out pulse mechanism is similar optically to the signature dot pulse mechanism in the interrogator head. However, for reasons of clarity the mechanism involved is not shown in Figure 4. In effect, what the read-out dot does is trigger a read-out pulse phototube at the end of the interrogation of one complete matrix. This read-out pulse phototube in turn directs that the hit detector be examined for a stored pulse, and that the hit detector then be returned to a condition for examination of the following matrix. In addition, if the hit detector is found not to contain a pulse, the read-out pulse phototube causes a pulse to be directed to the storage element (from which it goes to the recopy camera for actuation of the recopy mechanism).

<u>Multiple-phototube-blackout system.</u> In the sequential-blackout system, an attempt is made to economize on the number of phototubes required to interrogate a matrix by the use of flash tubes to examine the various submatrices sequentially, and by the development of a method whereby the light from the various submatrices can be transmitted to a single set of phototubes. In working with the sequential-blackout system, it has become

obvious that the major problem area is that of transmitting the light from the question masks to the single set of phototubes. The use of mirrors involves a difficult problem in adjustment and, since light coming from simple lenses is not collimated, the problem of handling divergent light rays can be very troublesome. Furthermore, the problem is not greatly simplified even if the number of phototubes is increased fivefold so that there is a single phototube for each element rather than one for each group. The problem of focusing the particular light spots which may occur upon the sensitive area of the phototube still is acute.

Conceptually, it would be possible to solve this problem by using a phototube for every possible dot (or group of dots that could conveniently be fitted over a phototube) in the whole matrix. In its most extreme form, this would mean that 9600 separate phototubes would be required. Even if a block of four or six dots could be directed onto the face of one phototube, somewhere between 1600 and 2400 phototubes would still be required.

However, it seems likely that much the same result could be achieved with a much greater economy in phototubes. A phototube measuring 1/4 inch in diameter is available. If the submatrix area on the film is optically enlarged sufficiently so that the shortest dimension of the dot is approximately 3/8 inch, it would be possible by placing such a phototube in this area to detect the presence or absence of light without using any special light transmission devices other than the enlarging lens itself. Although it is not feasible to employ 9600 such phototubes, it might well be possible to develop a patch panel into which phototubes could be fitted in any desired pattern. Specifically, if the film described in the discussion of the sequential-blackout system were enlarged so that the 1/4 inch phototubes could be used, a patch panel approximately 24 inches by 9 inches could be constructed for each submatrix. In such a patch panel there would be 40 double columns into each of which phototubes could be inserted in 24 possible positions. By making a square cartridge around the phototube it would be possible to plug the cartridge into the patch panel so as to make contact with metal channel strips. The patch panels, like IBM patch panels, would be completely removable from the machine. When put in place under the lens as question masks the metal channels for the 40 couble columns would plug into contacts leading to 40 amplifiers.

If two or more phototube cartridges were plugged in to a given channel, in such a manner that they were connected in parallel, a blackout would be required of all phototubes in order to prevent an output pulse from this channel. Such an arrangement could thus be used to read over-punches. For example, if three phototubes were placed in a single column representing in IBM terms the two overpunches and a single ordinary punch, black dots would have to appear in all three of these places in order for a hit to be registered.

If the metal channels were so designed that when more than one phototube cartridge was inserted in one channel they would be connected in series, a quite different effect would be achieved by the use of multiple phototubes. In this case the darkening of <u>any</u> phototube in a column by a black dot would be equivalent to a blackout for that entire column. Such a device would be useful for selecting ranges of IBM codes, where all that is required is that any one of a group of dots in a column appear. It would probably be possible, by designing the phototube cartridge and the patch panel appropriately, to allow either parallel or series connections of the phototube cartridges in a given column.

If separate patch panels were used for each of the submatrices, it would no longer be necessary to use a sequential method of examination, and therefore the need for triggered flash tubes would disappear. This simplification would not only reduce the amount and complexity of the circuitry involved in this part of the Rapid Selector, but would also remove a possible source of trouble in the failure or misfiring of flash tubes. Despite the substitution of a constant light source for flash tubes, however, the sequential examination of specific submatrices would still be possible. As long as signature control dots were still used to determine when a submatrix was aligned with its own question mask, it would be possible to examine any particular submatrix from one to five times: to accomplish this it is only necessary to arrange the circuitry so that the output of the phototubes is fed to the hit detector only for the periods when the submatrices and their corresponding question masks are aligned.

A final question that arises in the consideration of the multiple-phototube-blackout system relates to the complexity of the circuitry required. On the basis of preliminary investigation, no very great difficulties are anticipated. It is not necessary to wire for each of the 9600 possible phototubes. By using five patch panels with connections for 40 channels each, only 200 channels would need to be wired. It would be possible to get along with 40 amplifiers if they were triggered to be used sequentially with the different submatrices, but inasmuch as these amplifiers are of an extremely simple type, even 200 would not be very difficult. Regarding the need for phototubes, it is quite probable that in general a relatively small number of phototubes would be sufficient. In normal IBM punching there is only one punch to a column, so that only one phototube for each column questioned would be necessary. If a fairly simple question were posed of the matrix, for instance one involving ten columns, only ten phototubes altogether would be needed. Where over-punches are used, up to three phototubes would be required per column. Obviously, the more complex the question, the larger the number of phototubes that would be required. The phototubes themselves, however, are relatively inexpensive, and it would probably prove useful to have extra phototubes and extra patch panels on hand so that question panels could be made up in advance while the machine is working on other problems. In this manner the maximum amount of machine time could be devoted to selection.

The advantages of introducing multiple phototubes and patch panels seem considerable at the present moment, but it will be necessary to run tests to determine the complete characteristics of this particular system. The actual design of the patch panels may pose some problems, but it is believed that these will be comparatively minor in relation to the problem of transmitting light from the question mask to the phototubes in the sequential-blackout system.

E. Recopy Camera

Purpose

The recopy camera will rephotograph, on a separate roll of 35 mm film (which may yield either negatives or positives as needed) those units of information that the interrogator has registered as hits. Either the abstract alone or the abstract and the code will be copied, as desired in a particular instance.

Specific requirements

The recopy camera must be able to operate at the speed of the interrogator, taking any sequence of hits and misses--in extreme cases, either a long string of hits or a repeated sequence of one hit and one miss. It must be able to recopy the code area or not, as desired. Provision should be made so that exposed film can be removed for further processing at any time, not only when a reel is full; and rethreading of the camera should be accomplished simply.

Solution

The overall arrangement of the recopy camera in relation to the various components of the interrogator was shown in Figure 2. The master film passes from the interrogator through the recopy camera before it arrives at the takeup reel. The camera also contains a second, unexposed film, on which the recopying of appropriate information units is done. After consideration of the merits of various types of cameras, and after consultation with Ralph Shaw and Jacob Rabinow, it was decided to employ slit photography in this recopy camera. In slit photography, the recopy camera has no shutter. A slit through which the exposure is made is always open. The film being exposed is passed through the camera at exactly the same speed as the film being copied (in the opposite direction, since exposure is made through a focusing lens which reverses the image). Each time a hit is recorded, therefore, provision must be made to start the recopy film and get it up to the speed of the master film by the time the desired information unit reaches the recopy camera, and then to stop the recopy film after the desired information unit has passed.

Control of the recopy camera is accomplished by dots in the control columns of the master film, in much the same manner as the interrogator was controlled. As is evident from the block diagram shown in Figure 2, there must be a physical separation between the interrogating head and the recopy camera. Consequently, when the interrogator records a hit, some delay must follow before activation of the recopy camera, to allow time for the information unit in question to arrive at the recopy camera. The storage element in the block diagram is included to allow for this delay. When the interrogator records a hit, the hit detector directs a pulse into the storage element. After a time lapse corresponding to the time of transit of that information unit from the interrogating head to the recopy camera, the storage element delivers a pulse to the recopy camera. This pulse is used to prime the recopy camera mechanism--i.e., to indicate that the next information unit that passes is one to be copied. The actual activation of the recopy camera, however, is accomplished by dots in the control columns of the master film. When the recopy camera has been correctly primed by a pulse from the storage element, the read-out dot in the next information unit to appear will, by blacking out a phototube, trigger the recopy camera. When the matrix and its abstract have passed through the recopy camera, the camera is deactivated by means of a recopy stop dot placed on the master film at the end of the abstract, in an additional control column. When this dot passes the phototube in the recopy camera, the recopy camera mechanism is stopped. In the event that two hits follow one another, the delayed pulse from the storage element pertaining to the second information unit is timed to arrive at the recopy camera before the recopy stop dot from the first information unit, thus preventing the camera from stopping. It will therefore operate continuously as long as a sequence of hits is obtained at the interrogating head.

The acceleration of the recopy film to the optical speed of the master film is accomplished by means of a clutch mechanism and a flywheel which operates at the same linear speed as the master film. The flywheel will operate all the time. When the recopy camera is not in operation, the flywheel will be a small distance above the recopy film. When recopying is to start, the clutch mechanism will push the film against the flywheel and keep it there for the period of the recopying. This mechanism is copied directly from that designed by Dr. Rabinow for the Shaw machine. Experience reported by Rabinow and present experiments indicate that not more than a quarter of an inch of recopy film will be wasted by the acceleration of the recopy film to the optical speed of the master film.

A supply of film must be available in the recopy camera under constant tension, so that the tension will not change during the operation of the camera. To accomplish this, dancers (spring-loaded arms) around which film is looped will be required. These dancers operate so that as film is used by the recopy camera the loops become smaller, the dancers moving toward one another. Thus it is possible to have slack in the film between the reel and the recopy camera and yet to hold the film in constant tension. A means must also be provided for supplying film to the dancers in such a manner that the recopy camera will never have to take film directly from the reel. For this purpose it will be necessary to employ some sort of servomechanism related to the positions of the dancers, so that when the loops of film around the dancers decrease in size the reel itself will begin to feed film to the dancers. This synchronization does not need to be perfect, inasmuch as the dancers can provide for fairly wide differences between the amount of film being fed into them by the reel and the amount being taken from them by the recopy camera.

F. Viewer and Reproducer

Purpose

The recopy camera delivers undeveloped positive or negative 35 mm film. After the film is developed by conventional means, some mechanism is needed which will permit the analyst to inspect the film, to choose those frames of which prints are desired, and to obtain paper prints rapidly.

Specific requirements

Because of the nature of the abstract material, a very high quality of reproduction in the viewing mechanism is essential, both to insure accuracy and to prevent excessive fatigue on the part of the analyst using it. The process used to make paper prints should preferebly employ an instantaneous development process, such as the Land Polaroid process. Provision should be made so that a print can be made of any portion of a frame, as well as the entire frame.

Possible solutions

There are two general types of solutions which could be adopted. First, a conventional optical viewer, utilizing a simple projection lens, could be employed as the basic element in the system. Second, it would be possible to use a closed-circuit television system to scan and view the film.

If the first solution were adopted, it is expected that the viewer and reproducer could be constructed largely from components now commercially available. For the viewer proper, one of the presently available slide viewers could be adapted. For the reproducer, a Land Camera back might be adapted. These elements would be built into a table, and arranged so that both the film-loading mechanism and the finished print are readily accessible on the table top. This could readily be accomplished by employing a prism or a mirror in the path of the light from the film to the paper. Employing such a prism or mirror would also simplify the mechanism necessary to provide for copying a portion of a frame; by placing the lens and prism on motor-driven cams, it should be possible to obtain automatic reduction or enlargement of the image on the projection surface. If the film itself can be moved both laterally and longitudinally, the viewer could enlarge any portion of the frame he wished. Furthermore, if the reproducing mechanism is aligned with this enlarged image, prints of any desired enlargement could be made of any portion of a picture.

Instead of using conventional optical viewing, it might be preferable to utilize a closed-circuit television system. This possibility is being explored by the Agency, and it is believed that a much higher quality viewing system which would be easier for the analyst to use might result. By use of an electrical rather than an optical system, for example, it would be far easier to control the contrast of the image, and it would even be possible to reverse it from negative to positive if desired.

In consideration of the work being done by the Agency in this field, the development of the viewer and reproducer will be carried out in terms of their findings.

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III. Current Work Status

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A. Automatic [redacted]

Work on this machine started during the summer of 1952. The initial problem was to test whether or not the gear mechanism of the [redacted] could be adapted to extend the range of focusing. Th[redacted]

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itself was obtained toward the end of the summer. [redacted], together with several of the consultants, spent a considerable amount of time trying to see what use could be made of the existing Recordak components and focusing mechanism. It was decided at an early stage that the original [redacted] lens could not be used, because the camera head would be too close to the copy when small areas (i.e., 2 by 3 inches) were photographed, so that it would be very difficult to get proper lighting on the copy. Once this decision was made, it became obvious that it would be considerably simpler to redesign the complete head and table, rather than attempt to adapt it further. At this juncture, [redacted] made several trips to companies manufacturing such devices as automatic enlargers

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in order to inspect their methods of handling this problem. On the basis of these investigations and in consultation with [redacted], it was decided to employ a cam-operated gear mechanism to operate the lens. Detailed drawings of the complete system and specifications were made. After considerable investigation, it was found that the helical lens mount would have to be fabricated by an optical company, and the [redacted] was contacted. [redacted] was employed in making the detailed layouts from the preliminary sketches, in drawing up complete specifications, and in submitting lists of required components. All of these components were ordered from their appropriate sources.

A meeting of consultants on the [redacted] was held in December, and it was pointed out by Mr. Jacob Rabinow of the Bureau of Standards that the gear mechanism which was being employed would require high precision, and would be extremely costly to fabricate. At his suggestion, therefore, and with the help of [redacted] was redesigned to operate on the basis of a bell cam and an adjusting cam. The new designs were finished in mid-February, and from that point forward fabrication proceeded. During the last week in April, the [redacted] was completely assembled and in working order. In operating it, however, it was found that the hydraulic system and motor were too powerful relative to the task they had to perform, and set up considerable vibration in the whole system. To correct this, a new hydraulic system and motor are now being installed. Delivery of the completed [redacted] is expected very shortly.

B. Developer and Printer

25X1A5a1 As indicated above, this component is not considered part of [redacted] but is being developed independently.

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C. Encoder

Before it was decided to employ IBM punchcards as the basic source of coded information, a number of different procedures for placing black and white dots on film were considered. Among others, the use of a vidicon tube to put patterns of black and white dots on film was explored. With the decision to use IBM cards, however, it became evident that some sort of direct transformation method would be preferable. Experiments were made by [redacted] on the direct photography of IBM cards in the hope that the resulting dots on the film would be adequate for sensing. The main problems in sensing dots arise because of movement of the film from side to side as it passes through the film guide, and because of variations in the width of the film. (Very little longitudinal tolerance is needed, since it is obvious that at some time every point on the film will pass by a given point in the interrogating head.) Direct photography of IBM cards was found to yield dots so small in width that it would be necessary to employ a complex servomechanism to control the lateral movement of the film. It was therefore decided that an attempt should be made to develop a more efficient transformation of an IBM punchcard then could be obtained by direct photography.

The possibility of using a plastic framework to rearrange the pattern of holes on an IBM punchcard and make an optical transformation which could be photographed was next explored. The punch in an IBM punchcard is long and narrow in the longitudinal direction, whereas for successful interrogation a wide, short dot is needed. The IBM punchcard, furthermore, wastes considerable space between punches. The experiments with optical transformations, however, indicated that this would not be an easy solution, in that the development of complicated precast plastic shapes would be extremely expensive and probably fairly unsatisfactory.

Mapes and Prentiss therefore began to experiment with simple light rasters which were electrical transformations from punchcards. Certain of the consultants on the project contacted Remington Rand representatives, and obtained from them a used sorter which can be adapted to parts of the encoder. The mechanism for feeding and positioning cards can be used directly, and the component which senses holes in a column can probably be expanded to sense all columns simultaneously. At the present time, inquiries are being made regarding the simultaneous sensing devices which IBM may have. The problem of getting even lighting over the area of a dot andpreventing light transmission between dots is being worked on by [redacted] At this juncture it appears that short plastic rods, with a curved surface at the end toward the light source such that the light will be focused on the ground surface at the other end, will operate satisfactorily.

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D. Interrogator

As was indicated in the discussion of the interrogation system, a considerable number of interrogation systems have been investigated, and the major work of all consultants and personnel during the summer and fall of 1952 was spent on this topic. A considerable number of visits were made by the personnel working on this project to such places as the [redacted] Two conferences were held at Yale with representatives from the Department of Agriculture, the Bureau of Standards, [redacted] and the Agency. In addition, project personnel went to Washington to confer with Agency personnel and others.

The first actual tests of the interrogation components were made in an optical bench. It was in this static model that the sensing of directly photographed punchcards was tested and rejected. The feasibility of using flash tubes and rather small dots on film, however, was substantiated in these early tests.

To explore dynamic problems, a revolving disc was set up to operate in conjunction with the other components. To simulate operating conditions, the disc was made adjustable in speed and a stationary strip of film was set between a flash lamp and a phototube. Along various radii of the disc different numbers of holes were drilled to simulate the holes in the interrogator mask. Thus the system is dynamically equivalent to that of the sequential-blackout interrogator, but in this particular unit the film is stationary and the mask (disc) moves, whereas in the actual interrogator the mask would be stationary and the film would move. This model eliminates the necessity for construction of the main film drive and gates until later in the development. The diameter of the disc and of the holes and the number of holes were all chosen so that when the disc is rotated at the speed that gives the same number of light flashes per second as will be used in the final system, the duration of the control phototube output pulses approximates those expected in the final system. The exposed area on the film is of such a width that the time required for one interrogating hole to cross the image of this area is equal to the time that will be required for the image of one dot on the film to cross a hole in the interrogating mask in the final system. In the disc system, the light that passes through the control hole falls upon a phototube. The output pulse, after amplification and shaping, is used to fire the flash tube. A variable delay makes possible adjustment of the time of flash so that the flash occurs when the main holes in the disc are in the desired positions. A second phototube responds to light passing through the film and the main holes in the disc. In this manner, the light passing through one open hole can be compared with that passing through one or more holes covered by exposed film. This test set-up is designed to: (a) determine the maximum number of dots that could be examined accurately with different film densities, (b) investigate the circuitry necessary to perform the interrogation, (c) subject the critical components, particularly the flash lamps, to life tests, and (d) determine the electronic factors limiting the maximum speed of operation of the proposed design. Obviously the problem of lateral movement of the film cannot be studied with this particular model. The preliminary tests have been very helpful, especially with respect to circuit design, and have led to several changes in design and adjustment. The area of permissible operations is beginning to assume definite dimensions, and there has been no indication that in the areas covered by these tests the proposed system will not work satisfactorily. Both Mapes and Hartman did considerable work on this part of the project.

Anthony Franco fabricated many of the precision components, and Guye Cappiello worked on the electronic components.

Simultaneously with the work on the disc model, experiments were also being carried out on the problem of transmitting light from the interrogator mask to the phototube. Most of the work in this area has been devoted to the light piping properties of methyl-methacrylate plastic rods, particular attention being paid to light transmission efficiency, light loss from the sides of the rods, and uniformity of the light across the exit cross section of the rod. Freedman has carried out much of this work. Tests on straight rods have been quite satisfactory, but tests on bent or tapered rods indicate that the designs used up to the present time will not meet the necessary specifications. In general, there is excessive loss of light at points of bend or tapering, which reduces the light transmission efficiency and may cause interference in adjacent light channels. Furthermore, the sides of the plastic rods function like mirrors: a beam of light is reflected from side to side, so that the final output from a rod is not an even diffused light, but rather a series of separate beams. It is such considerations that have strongly suggested that the use of multiple phototubes in patch panels might be a simpler and more efficient manner of constructing the interrogator.

As yet, actual work on development of patch panels has not been extensive, and most of the design problems are still in the discussion stage. Some experiments, however, have been carried out with the specific phototubes in question, testing their sensitivity and response pattern to dots projected from film. Amplifiers and circuits have been designed to go with these phototubes, and there has been every indication of a high degree of success in this direction. The work in this area has been carried out by Mapes.

E. Recopy Camera

At the present time work on the recopy camera is concentrated on the design of the clutch mechanism. Experimental models have been set up, and their characteristics have been studied. Tests are now proceeding to determine the conditions required to meet the specification of accelerating a loose strip of film from a standstill to a speed of 120 inches per second in a time of less than two milliseconds. This work is being carried out by Hartman. As soon as the design of the clutch mechanism with loose film is determined, further work will proceed upon the design of the dancers and the servomechanism required for the film drive of the recopy camera.

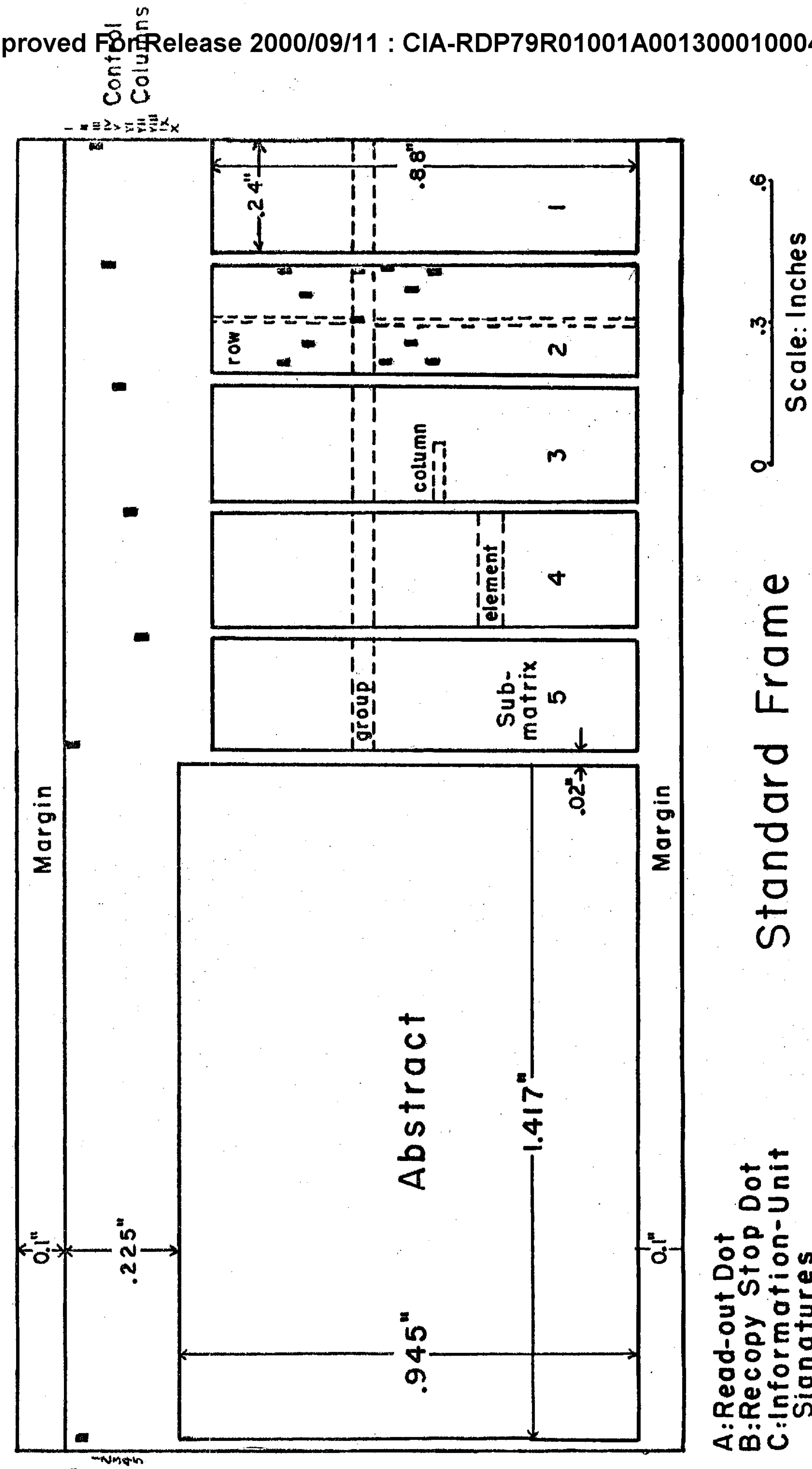
F. Viewer and Reproducer

As yet, no specific experimental work has been carried out on the viewer and reproducer. Some discussion of design problems has occurred, and certain components of the reproducer have been ordered. It is hoped that work can proceed at a faster pace when more personnel is available during the summer.

G. General Direction of the Project

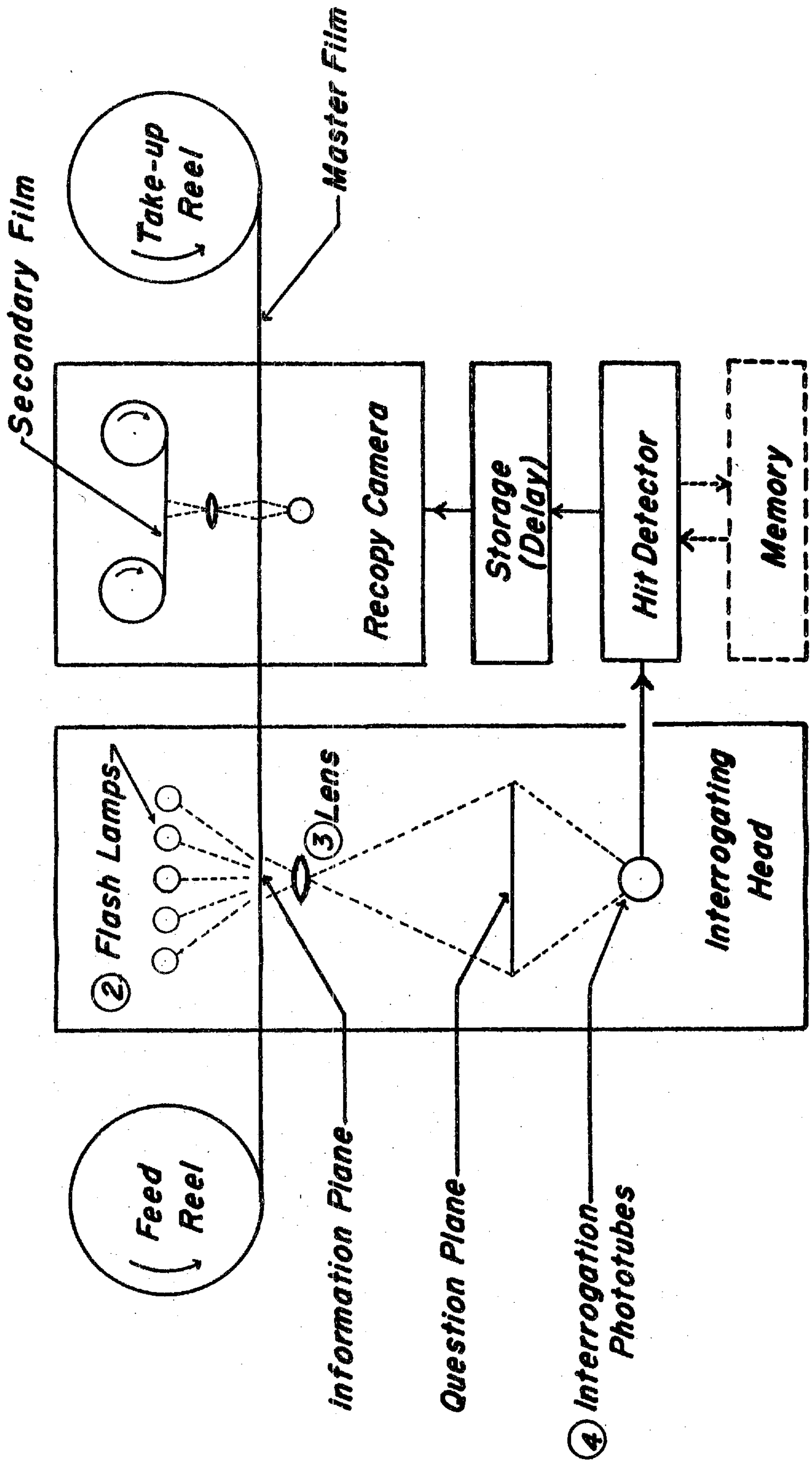
The general direction of the project has been undertaken by consultants drawn from the School of Engineering and the Department of Economics. All consultants met regularly once a week for about three hours; this meeting was used to discuss the results of the work done during the preceding week and to plan the experimental work to be carried out in the following week. In addition to these regular meetings, a large number of special meetings involving some of the consultants were held from time to time on various sub-topics. The consultants also took an active role in the actual design and fabricational work associated with the various experiments, working closely with the graduate students at all times.

In addition to the four graduate students, Freedman, Hartman, Mapes, and Shinn, the one undergraduate student, Prentiss, and the three technicians, Cappiello, Franco, and Hewitt, mentioned above, four additional undergraduates, all on part time, have been used on general construction and operation problems.



Standard Frame

Figure 3



LAYOUT OF RAPID SELECTOR

FIGURE 2

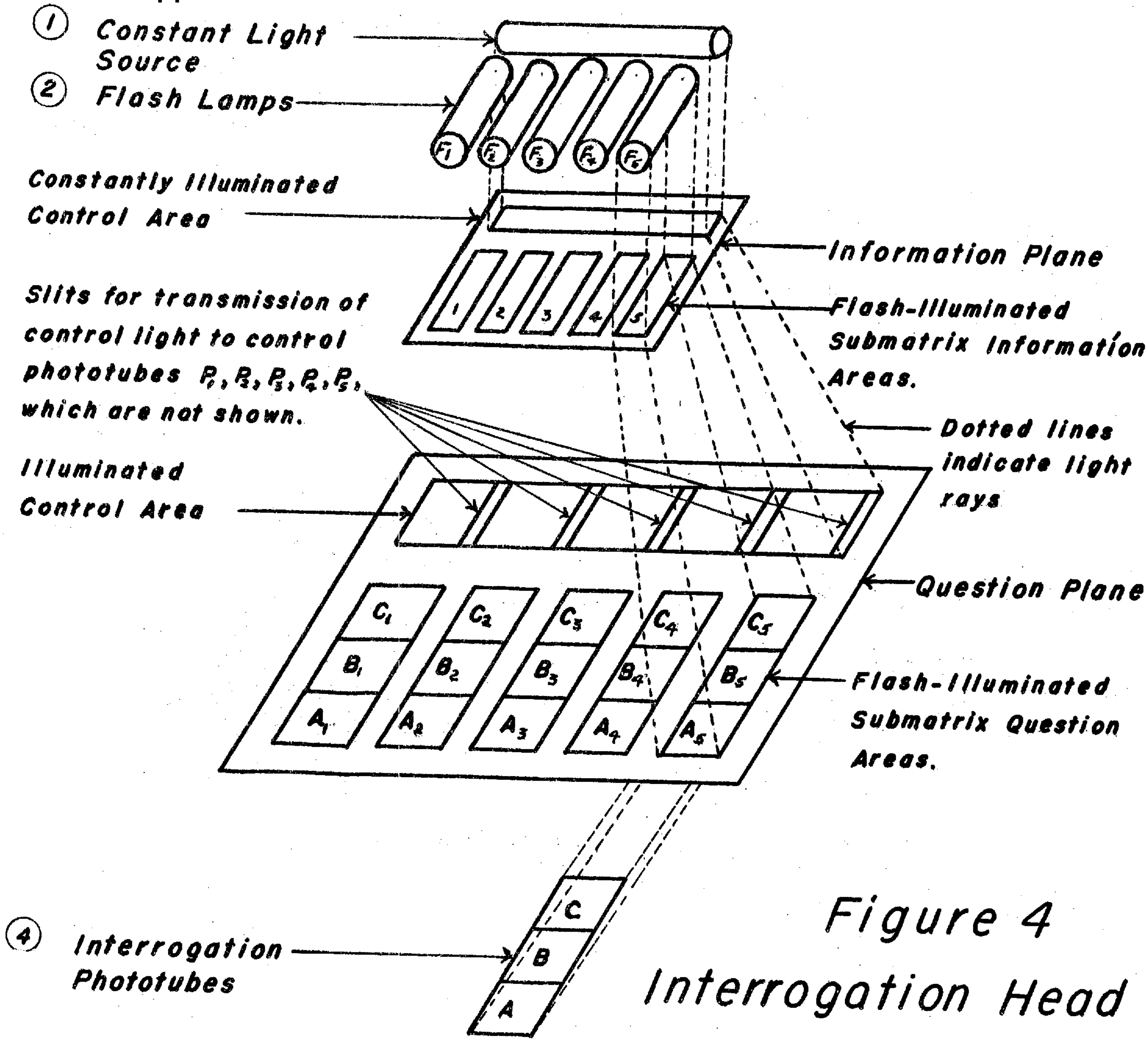


Figure 4
Interrogation Head

The information plane is projected onto the question plane by means of a lens (not shown).

Light through regions marked A, B, C, etc. is collected by interrogation phototubes A, B, C, etc., respectively.